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M A R I N A B A Y S A N D S



# Bad Actor Elimination in Pumps

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# Presenter/Author bios



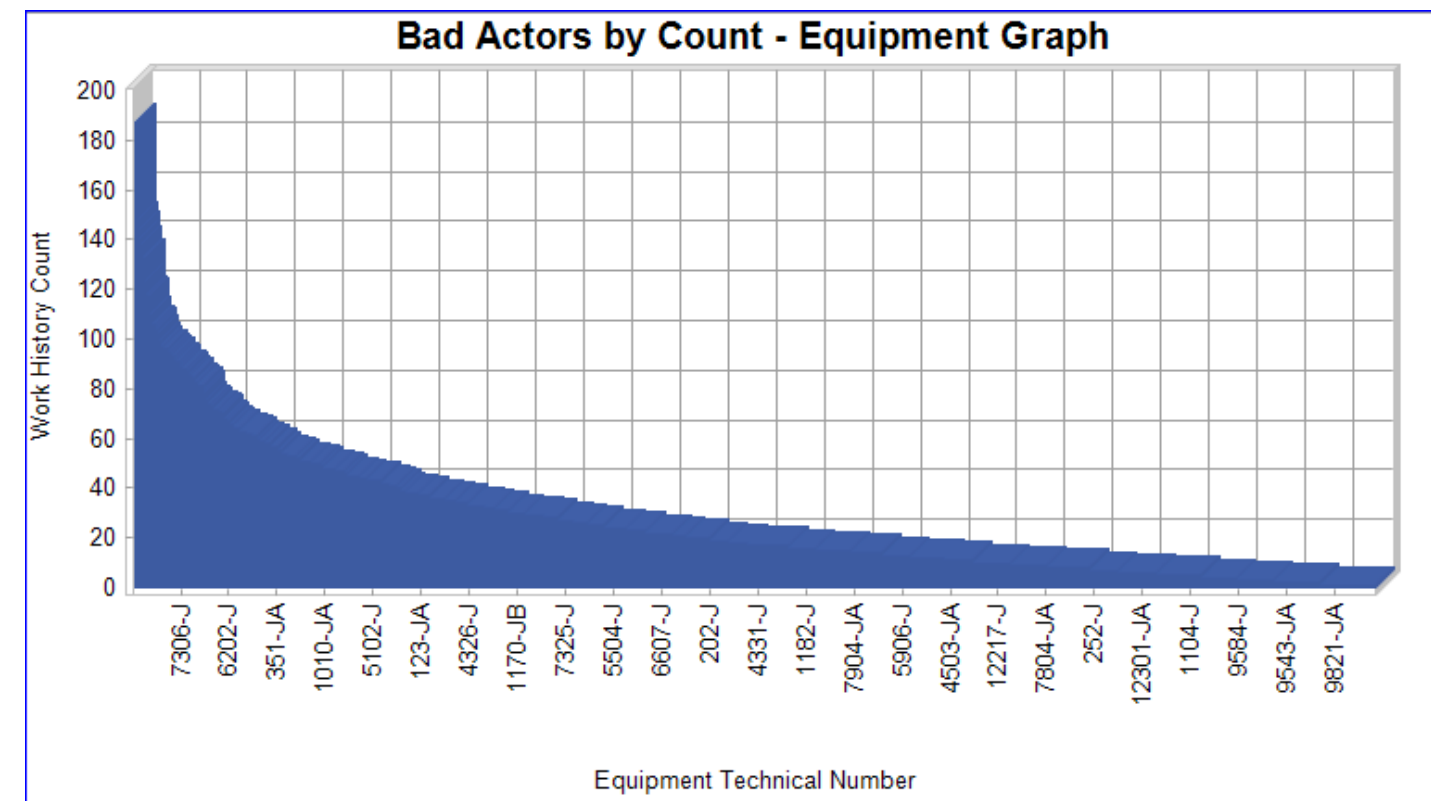
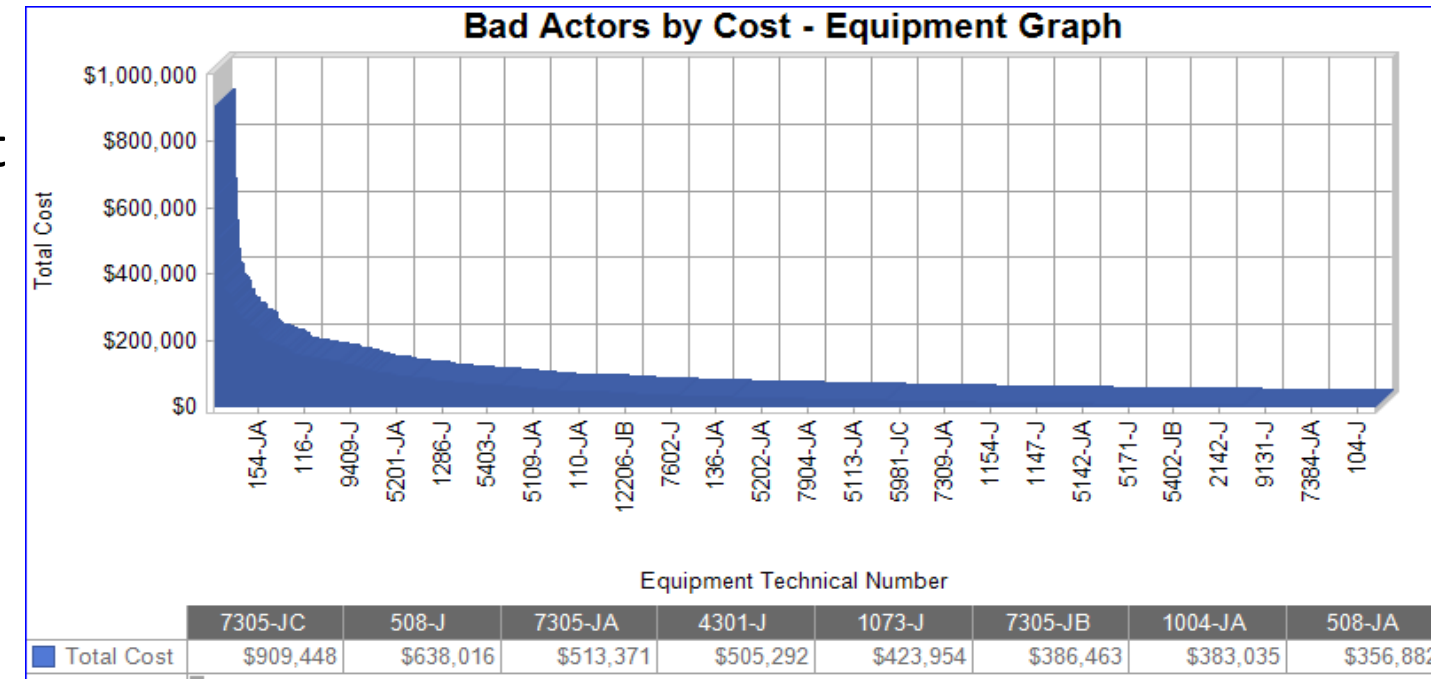
**Vasanth Bhat** is a Integrity Manager at Singapore Refining Company ( A joint venture refinery between Chevron & Petro China). During his last 6 years with SRC, his main role has been to support all technical and asset management issues with regards to rotating machinery in the refinery. Prior to this, Mr. Vasanth had over 19 years of experience in various roles as consultant , Sales , Reliability & Maintenance engineer in organizations in India , Middle east and Singapore. Mr. Vasanth has a B.E. degree (Mechanical Engineering, 1989) from Manipal Institute of technology – India and is a certified Category IV Vibration specialist by Vibration Institute USA . He is currently pursuing a Masters Degree in Rotating Machinery from the University of Zaragoza (Spain)



**Thangavel Suthan** is a Senior Reliability Engineer at Singapore Refining Company. Mr. Suthan has over 10 years of experience in commissioning, maintenance and condition monitoring of rotating equipments in petroleum refinery, gasification plants and air separation units. He is a certified vibration analyst (ISO CAT-II) with hands on experience in trouble shooting of turbo machineries, reciprocating compressors and centrifugal pumps. Mr. Suthan holds a Bachelor Degree in Mechanical Engineering (2005) from Coimbatore Institute of Technology, India and also Master Degree in Systems and Project Management from Nanyang Technological University, Singapore (2015).

# Bad Actors

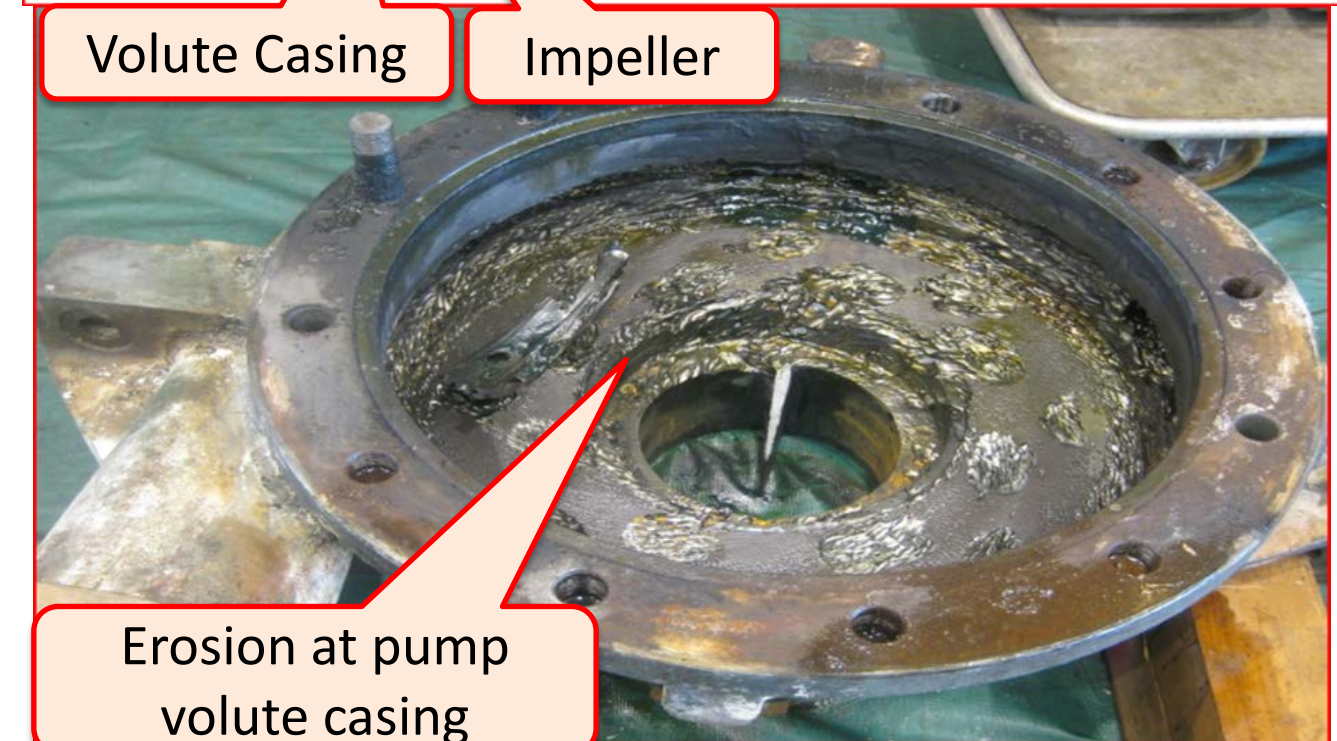
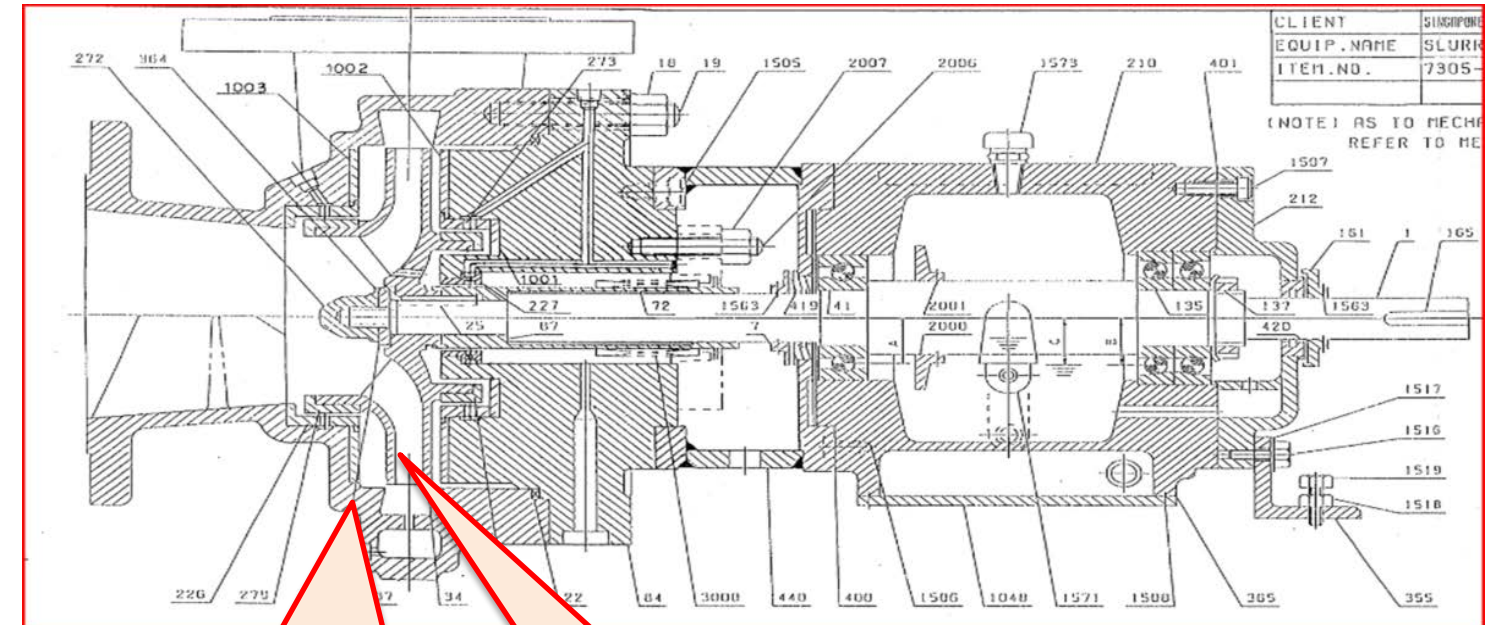
- Most industry end users reckon more than 90% of their assets perform to the required expectations and it is that balance 10% which brings down availability, results in high costs and possible safety related incidents. The
- Bad Actors are identified using Asset Management Systems or Computerized Maintenance Management Systems (CMMS) systems which can show where the organization is spending most of its efforts in terms of man hours or spending.
- As can be seen by adjoining plots in most organizations a few assets create the majority of the pains.
- A systematic cross discipline approach, involving identification of failure causes, carrying out Root Cause Analysis and recommending appropriate actions so that these root causes could be addressed will help to eliminate these expensive failures.
- The presentation explains 3 such cases which followed a process as mentioned above and had successful outcomes.





# Case 1 : Slurry Bottoms Pump

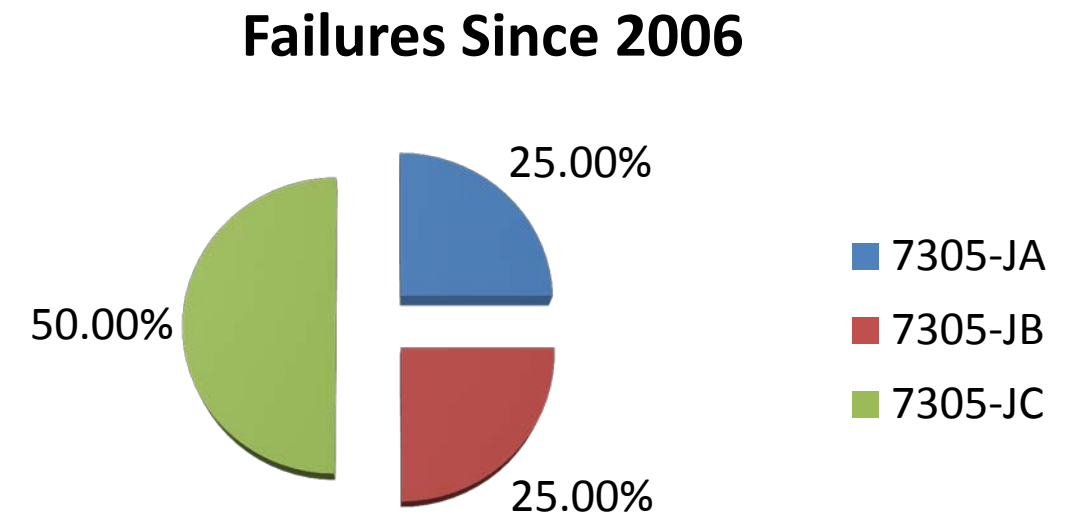
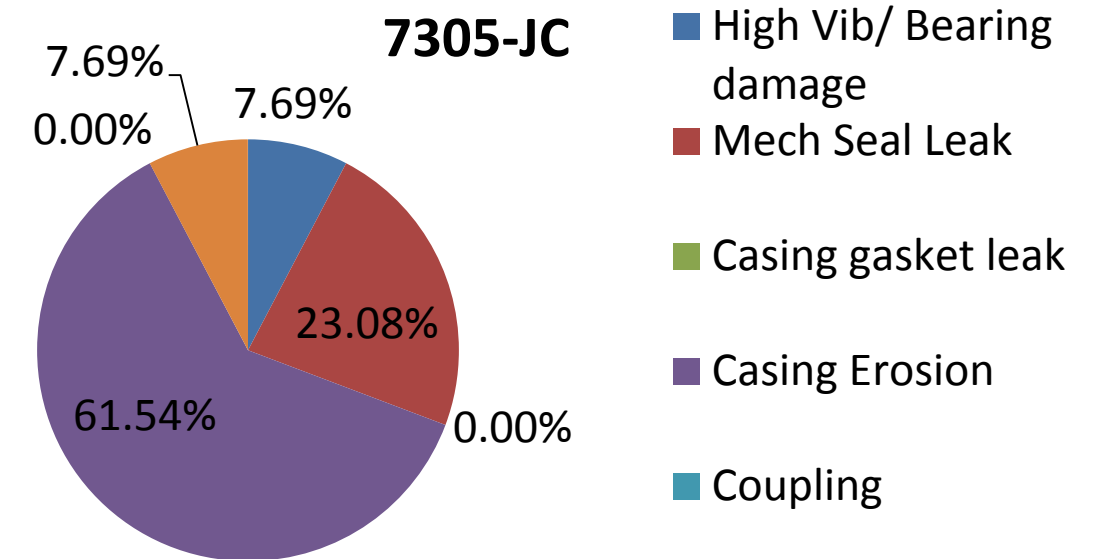
- Pump installed in the main fractionator bottoms circuit of a typical FCC plant.
- The pump handles a mixture of slurry and hydrocarbon at a temperature of 360 Deg C.
- In this application we had three pumps with 2 in continuous operation and other as a stand by unit.
- Pumps driven by general purpose steam turbine at 1800 rpm.
- The pump complies to API 610 and is provided with double seals with plan 54 seal flush plan.
- Due to the nature of pumping liquid, special pump metallurgy and casings are protected by metal wear plates which could be replaced when worn.



# Present Known Issues – Why a Bad Actor

- Heavy erosion of pump internals observed during routine inspection / maintenance.
- Pin Hole leak in the casing causing a product leak out.
- Frequent suction strainer plugging.
- Frequent discharge Non-Return Valve (NRV) passing issues.
- Occasional product leak from pump suction flange and casing flange.

All these resulted in these pumps being the ones on which highest maintenance expenditure was made.





# Failure Cause - 7305-JA, JB & JC (Continued)

## Observations:

- Casing erosion is the major failure cause for all three pumps.
- Casing erosion accounts for almost 92% of repair cost in JA & about 72% in JB & JC.

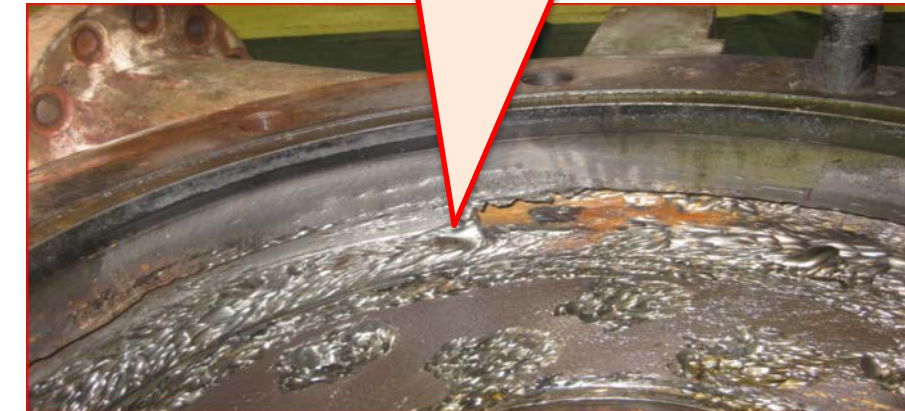
## Conclusions/Analysis :

- Is there a good pump out of these 3?
  - Not really. From the data it is observed that all three pumps fail at a certain interval. It is just a matter of time when it occurs.
  - Pump JC accounted for higher failures and higher repair cost because of higher running hours compared to others.

## Top Failure to Analyze :

**Out of all failure modes, casing erosion is the most dominant failure with high impact on repair cost. 2<sup>nd</sup> most dominant failure cause is bearing failure**

Erosion at volute casing tongue



Erosion at pump head patch plate

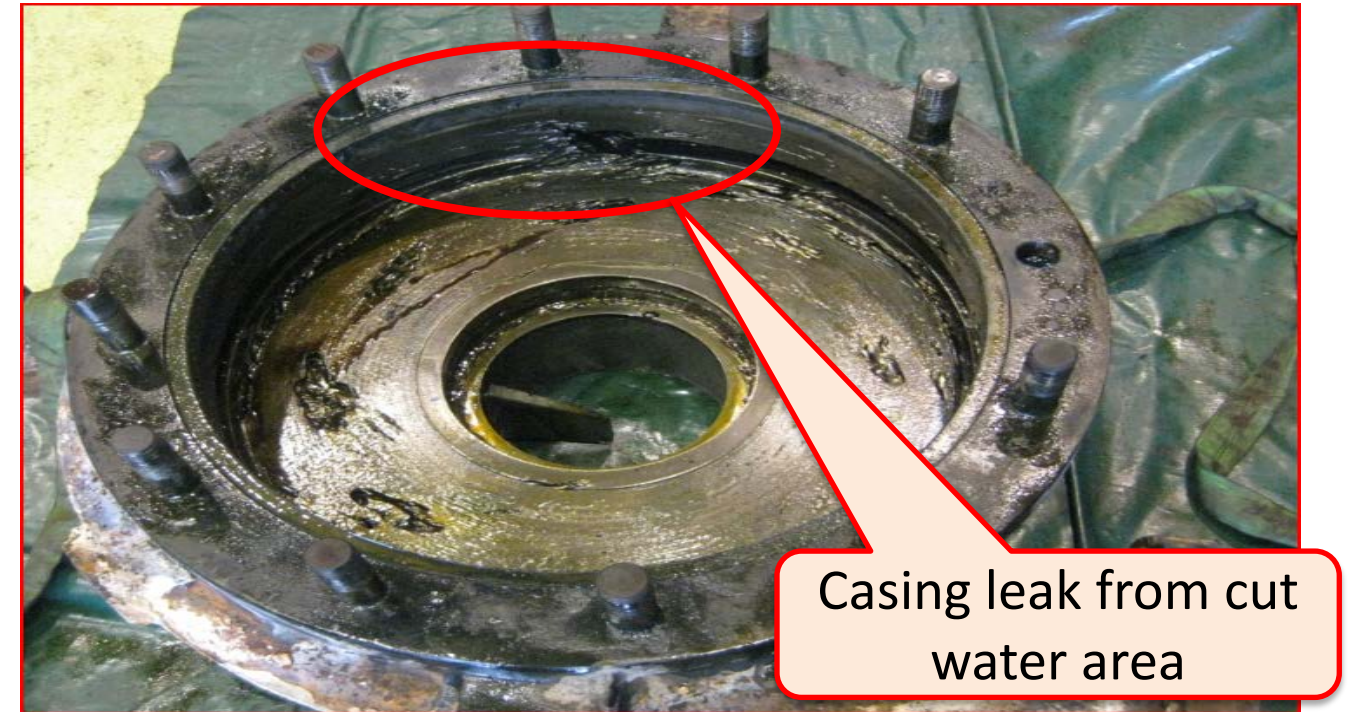
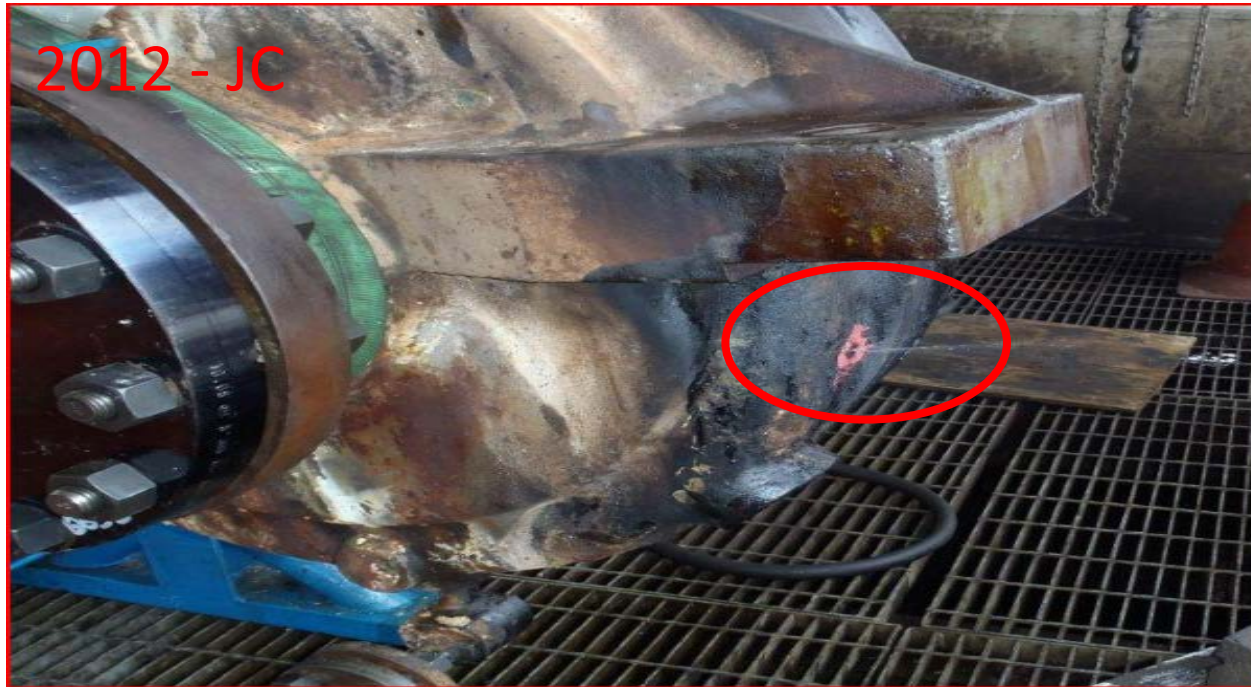


Erosion at impeller pump out vanes





# Casing Leak Locations



Casing leak from  
suction nozzle

Casing leak at:

1. Suction nozzle
2. Casing volute - cut water area



# Volute Casing Erosion Pattern

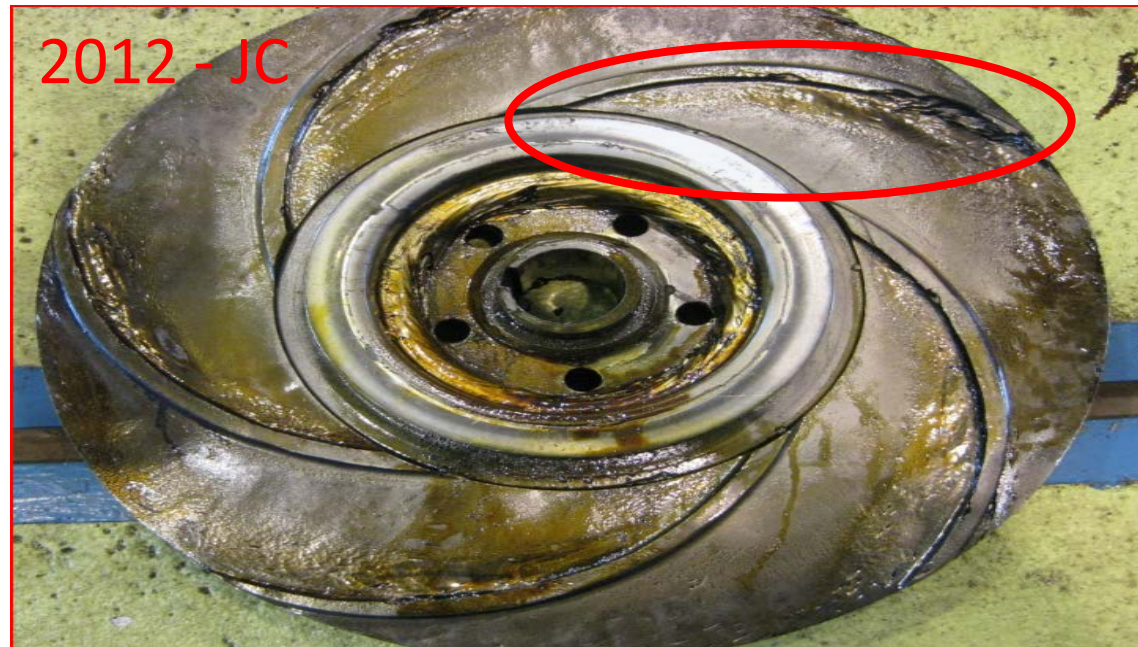


Erosion mainly occurs at:

1. Cut water area
2. Grub screw area – not hardened locations.
3. Suction wear ring area



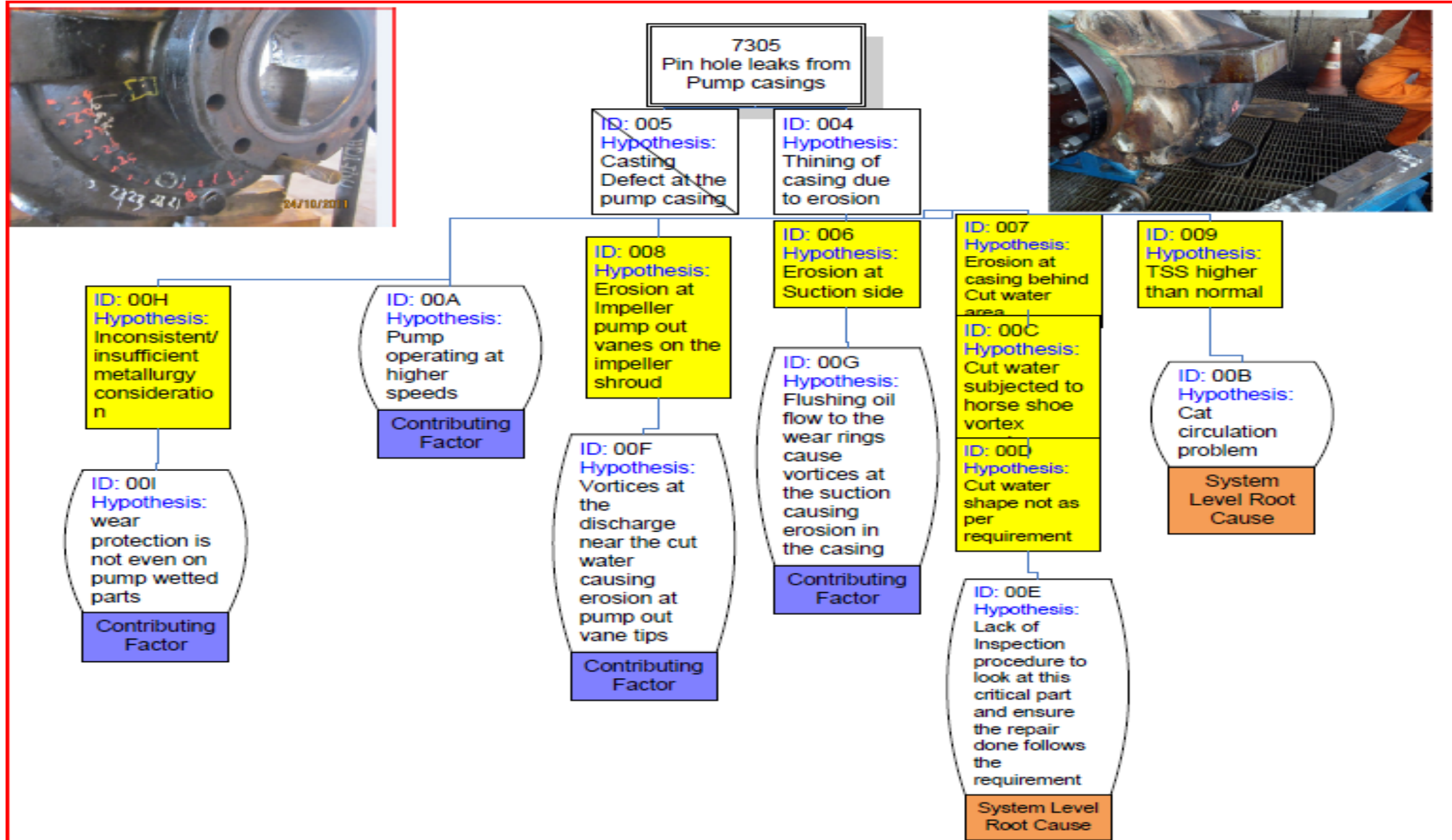
# Impeller Erosion Pattern



- Erosion starts at pump out vane edges and propagates to ends



# Why Tree for Casing Leak Failure





# Key Issues relating to casing erosion

- Researches has shown pump erosion has direct relationship with pump speed . Pumps running at lower speeds tend to have longer life.
- Due to abrasive solid pumping, these pumps are equipped with flushed wear rings. The concept here is that clean liquid is introduced into the wear rings annulus in an attempt to dilute the solids concentration and reduce the wear rate. Experience shows that the high intensity turbulence created by the flush flow can often be counterproductive. In fact, the additional turbulence can cause accelerated ring wear. Figure shows a typical flushed wear ring that exhibits the extreme damage that is often seen. Current recommendations is to stop the flushing oil flow and hence reduce the erosion.



# Current Issues

## Pump Metallurgy:

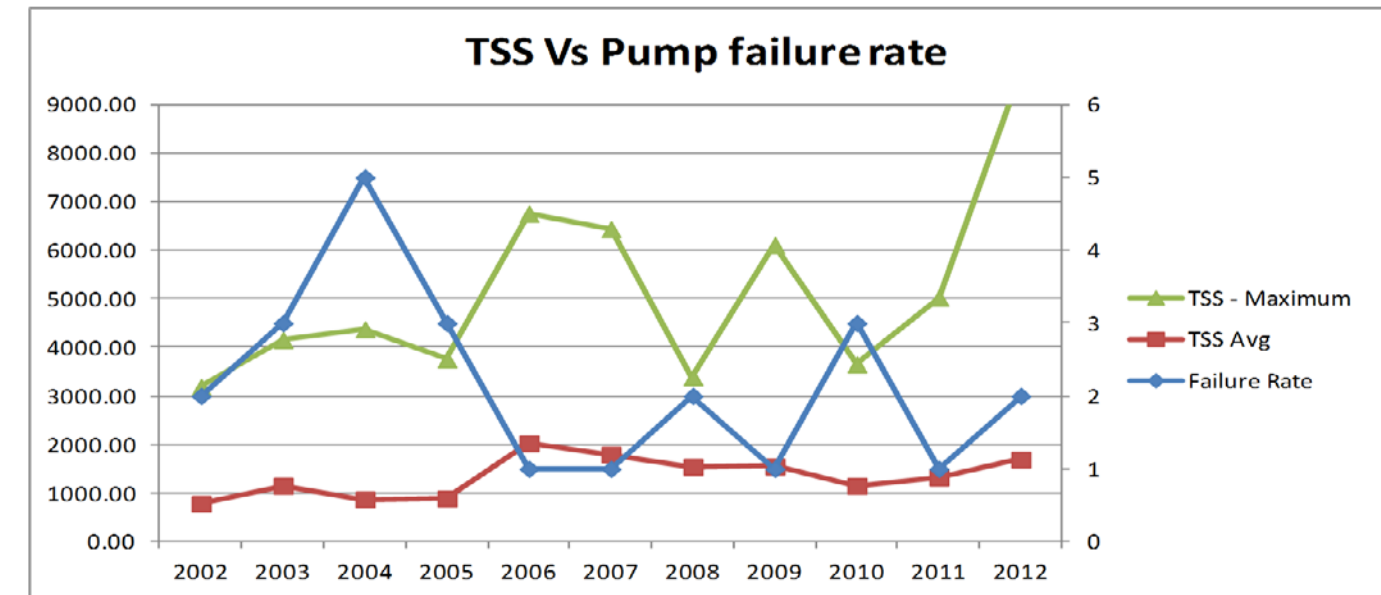
- Are we using the right metallurgy for pump parts? What are all the recent developments in wear protection? *Severe erosion indicates need for improved wear protection.*

## Is Repair Method Good:

- What is the extent of damage? Are we doing the right thing by repairing locally? Is repaired pump as good as original? *Erosion is severe in all part of the pumps. Repaired pump may not be as good as the original as erosion occurs at inaccessible areas which can not be properly repaired and/or hard faced.*

## Pump Design:

- Is this pump design (with patch plates) suitable for this service? What is industry best practice? *Many other refiners use similar pumps and are getting an MTBR of about 2 years.*



## Total Suspended Solids (TSS) Content:

- What is the design TSS content in slurry oil? Can we reduce TSS content to less than 1000 mg/l? Why is TSS content more in recent times...Especially after Plant Turnaround (TAR) 2011? How we can improve this? *In year 2012 it reached a maximum of 8000mg/l . Failure trend follows the high TSS content in slurry oil.*



# Pump Metallurgy Comparison

Pump Part	Base Material ( JIS standards)	Wear protection	Observation	Suggested Process	Best Practice	Reference
Impeller	SCS1T2 (Corrosion Resistant Cast Steel)	None	1.Heavy erosion at trailing edges 2. Indication Eddy flow erosion	OEM suggested Vacuum Nitriding	Boron diffusion coating	Nitriding hardens the external surface thus improving wear resistance
Casing	SCS1T2 (Corrosion Resistant Cast Steel)	Nitrided	1. Heavy erosion at inlet nozzle, liquid exit tongue area	OEM suggested Tungsten Carbide coating	Jet Kote <sup>®</sup> II or Equivalent	Tungsten Carbide has very high hardness and high wear resistant. But limited by line of sight process
Pump Head	SUSF410B	None	1.Erosion at throat bush area	Colomonoy #760 <sup>®</sup> or IBTCC <sup>®</sup>	Jet Kote <sup>®</sup> II or Equivalent	Wallcolomonoy <sup>®</sup> / Kenna Metal <sup>®</sup>
Wear rings/ patch plate	SUS403	Colmonoy #6	1. Heavy erosion at water cutting angle areas 2. Heavy erosion at areas which not coated (grub screw area)	Tungsten Carbide	Boron diffusion coating	Tungsten Carbide has very high hardness and high wear resistant. But limited by line of sight process

# Objectives for Bad Actor Discussion

## Objective:

- To achieve minimum service life of 2 years.
- To minimize the damage on pump parts and reduce average corrective maintenance cost by 20-30%.

## Gaps:

- *How is pump cavitation and strainer cleaning measured?*
- *How is pump performance monitored?*
- *How do we monitor the effectiveness of improvements like new metallurgy /new coatings etc...?!*



# Corrective Action Plan

- Reduce Total Suspended Solids (TSS) in the circuit back to normal level and inform when exceeding normal level.
- Reduce operating speed of pump to 1500 rpm, ensuring no drop in process control .
- To mitigate the hidden failure mode it is recommended to carry out a visual inspection of the pumps (intrusive ) with 1 year operating time.
- Discuss with OEM to explore the possibility to eliminate flushing oil to suction side wear ring and remove the back vanes on the shroud & other improvements in terms of coating and heat treatment for the pump wetted parts.
- Long-term Spare Strategy :
  - Keep one complete set of spares for the pump in the warehouse.
  - The removed pump to be repaired with close quality control on the repair.
  - Always ensure one spare pump is kept ready for installation.
- Change coating to Tungsten Carbide coating and coating of liners to be done after seal welding the locking screws into the casing. Tungsten carbide coating has much better erosion resistant properties compared to Colmnoy 6 coating currently used.



# Results of the recommendation

- Pump Last Casing Renewal: 4<sup>th</sup> May 2012
- Running Hours Since Last Repair: 8500 hrs (12 months approx.)
- Pump Component Details:
  - Volute Casing – **New** Casing coated with Tungsten Carbide – by OEM
  - Impeller – **New** (Vacuum Nitrided) by OEM
  - Pump Head – **Old** – Colmonoy #6 coated by Local Repair Shop

New Condition



Present



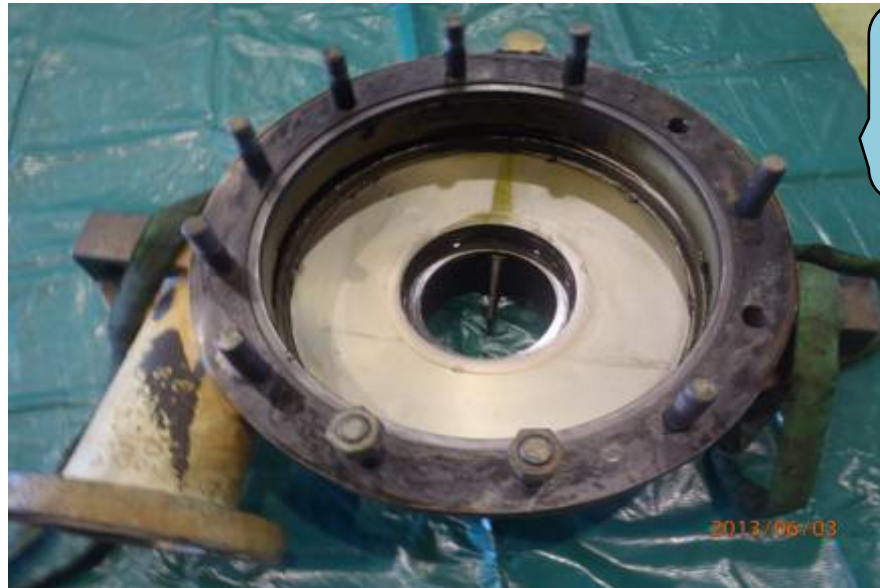
Eroded cavity  
10mm deep x  
5mm width



## Volute Casing - Observations



New  
Condition –  
WC Coated



Present  
condition

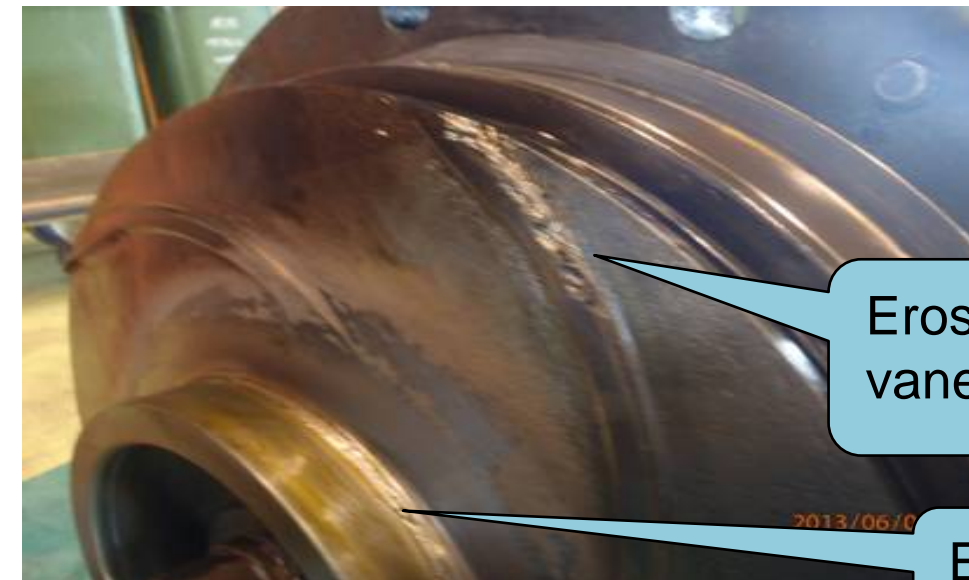
### Observations:

- Shows erosion at cut-water exit area.
- Shows erosion pitting on volute area.

## Impeller - Observations



New  
Condition



After 12  
Months

Erosion at Pump out  
vane leading edge

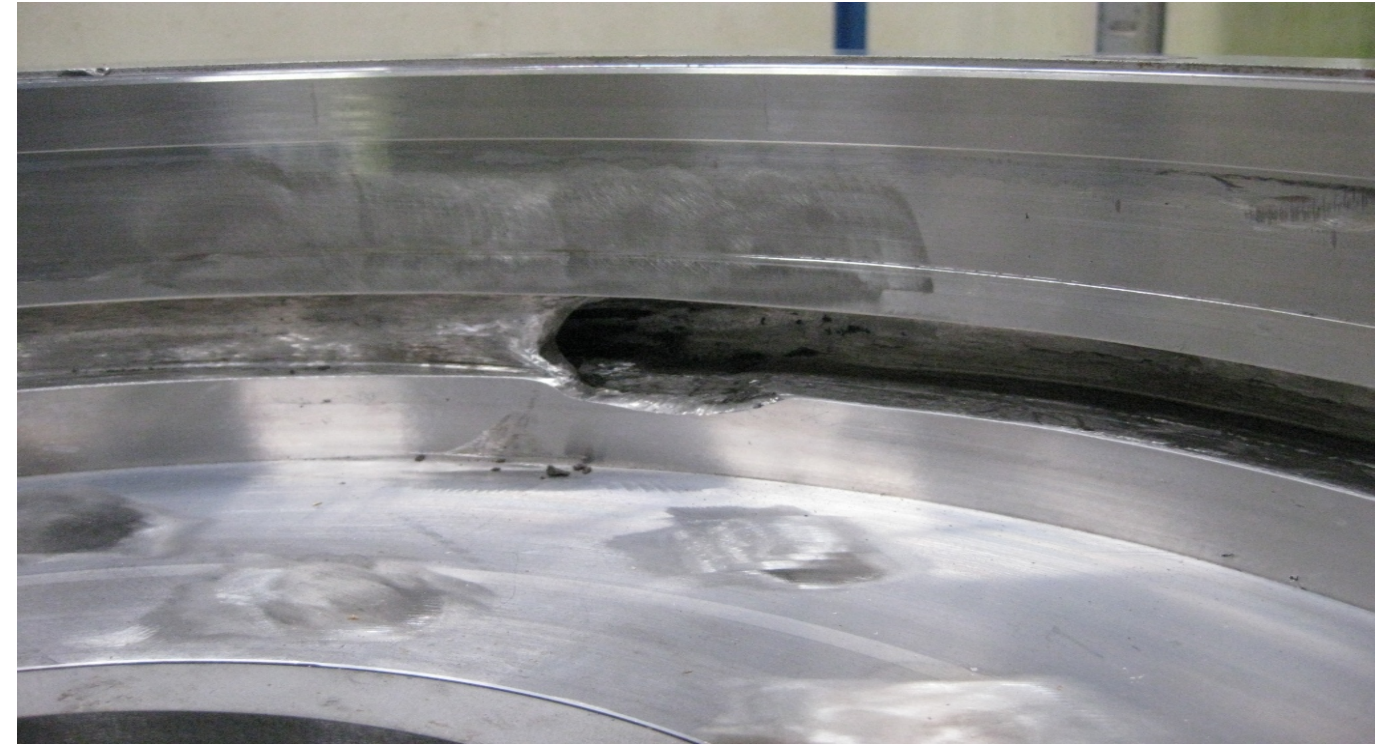
Erosion at Wear-ring  
neck

### Observations:

- Shows initial stages of erosion at pump out vanes and impeller wear ring neck area.

# Way Forward

- Max size impeller to be stocked in warehouse. This would help to bring down the speed further.
- Tungsten carbide coating is effective so would remain the repair technique for present moment.
- To improve the cut-water erosion, a stellite insert will be used at the critical area.
- OEM has confirmed that the flushing oil to the suction wear ring could be stopped and the impeller back vanes could be removed without any effect to the pump bearings.





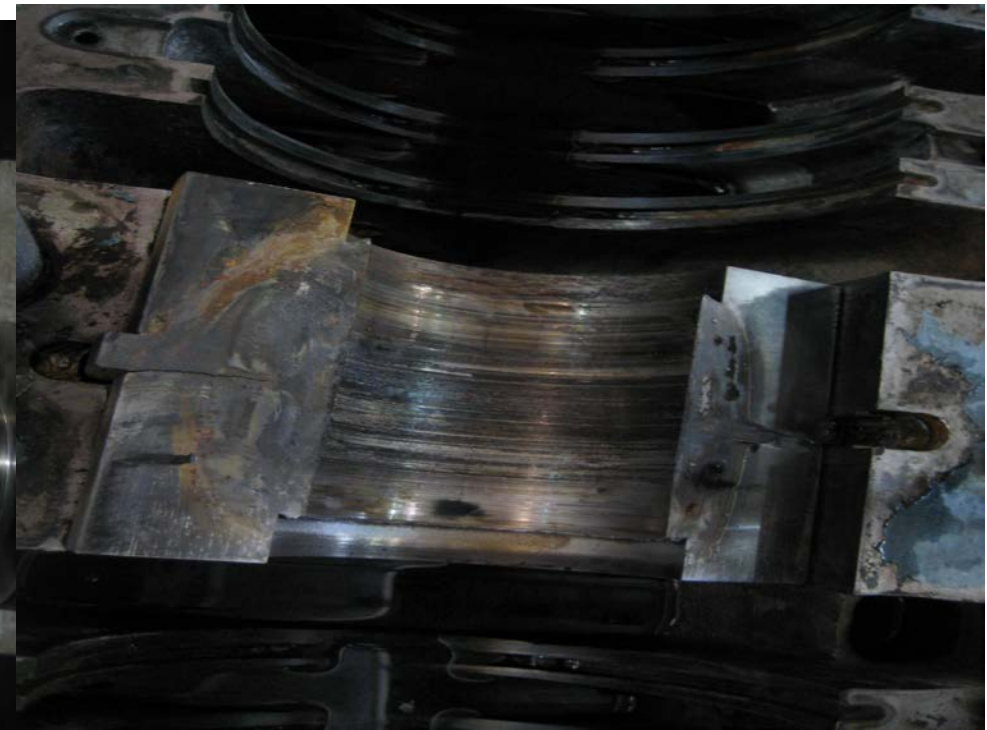
# Case Study 2: Lean MEA Pump

- 14 Stages
- Flow : 500 gpm
- Discharge pressure : 1400 Psig
- Suction pressure : 0.4 psig
- RPM: 2960
- Motor size : 640 HP



# Issues with the pump

- Multiple seal failures
- Seizure of the rotor
- Rotor breakage
- High wear & tear to the casing internals



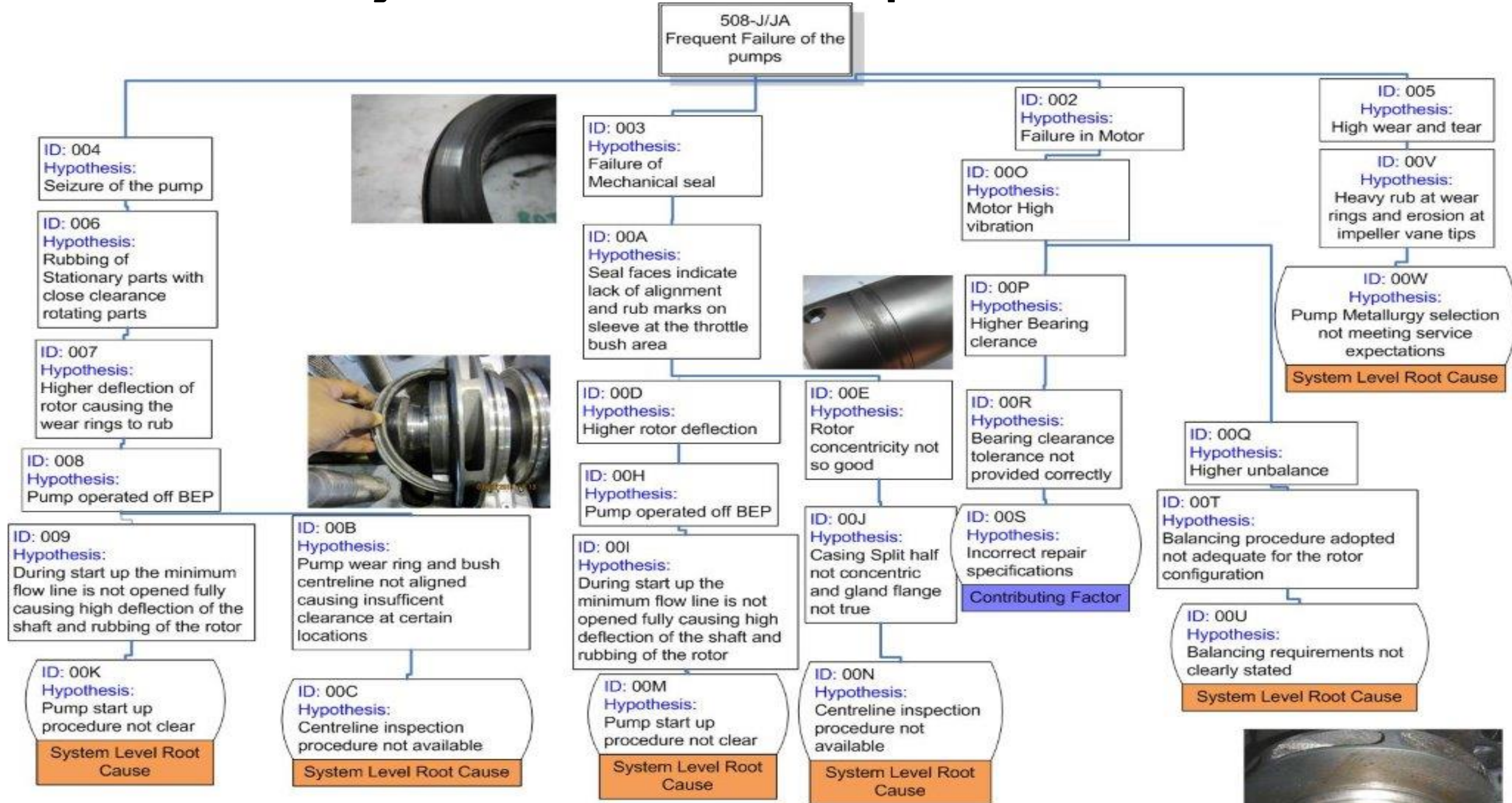


# Why A Bad Actor

- High repair costs per event and number of major events.
- Limited support from vendor
- Sensitive to operating conditions.
- Significant damages to major components such as bearing housing , casing & rotor.



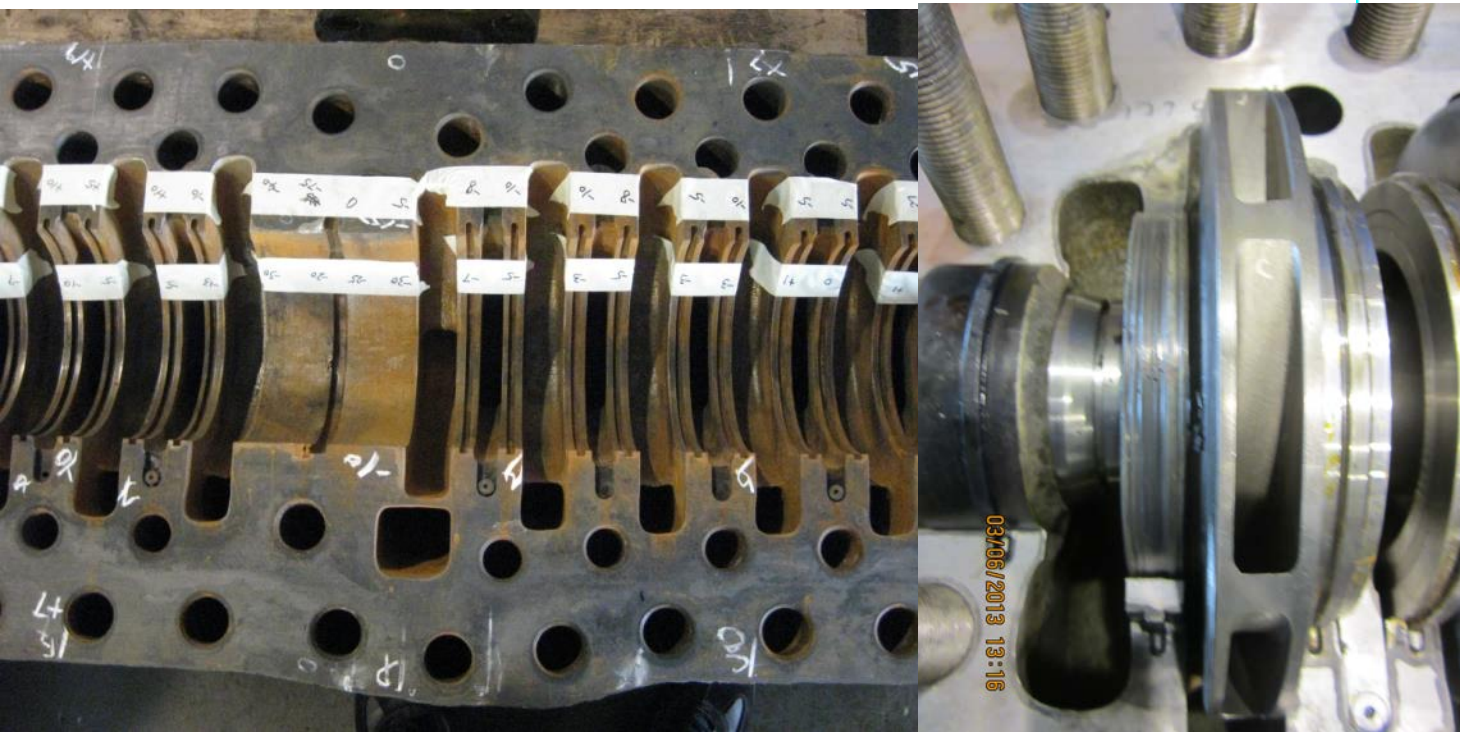
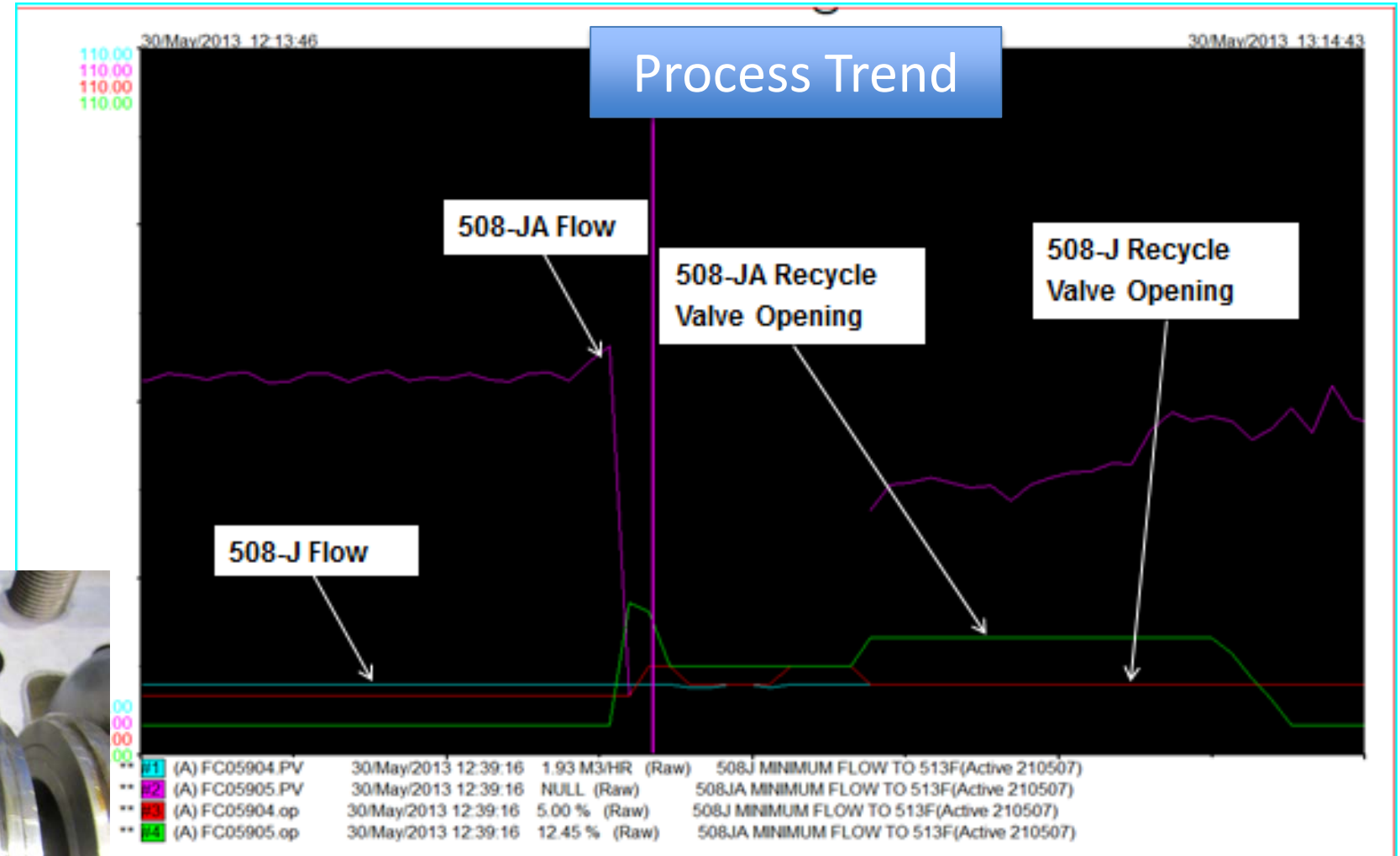
# Why Tree for Pump Shaft Failure





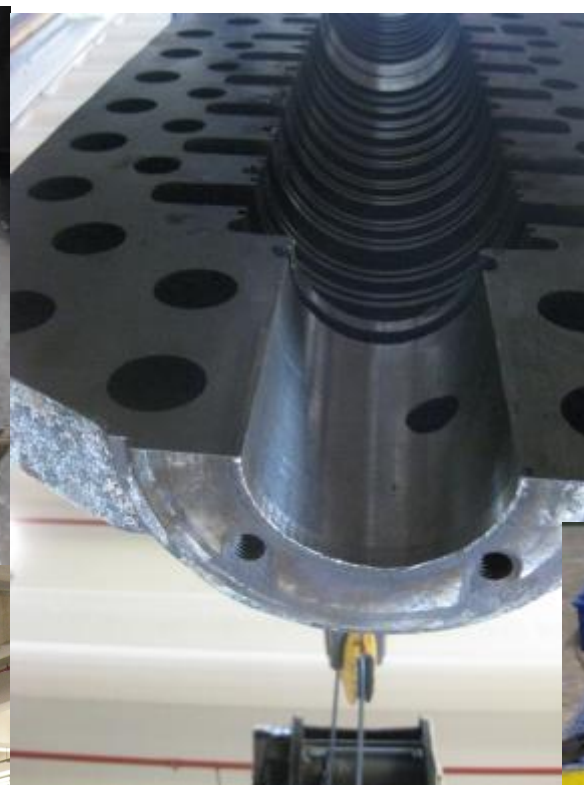
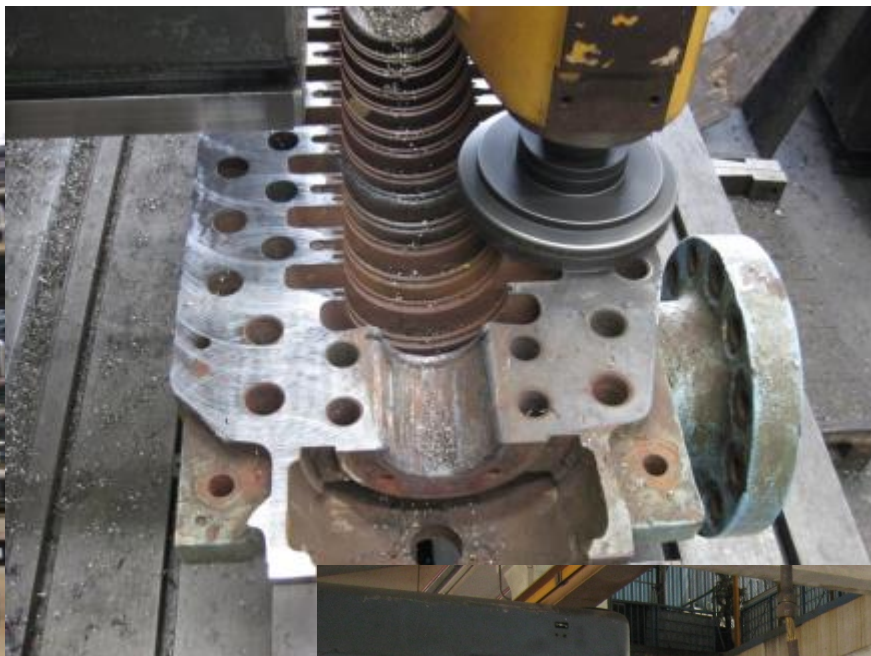
# Root Causes

- Operation procedure of the pump during start up.
- Design of the pump vulnerable to seizure.
- Repair standards of the pump not the levels expected.





# Extensive repairs





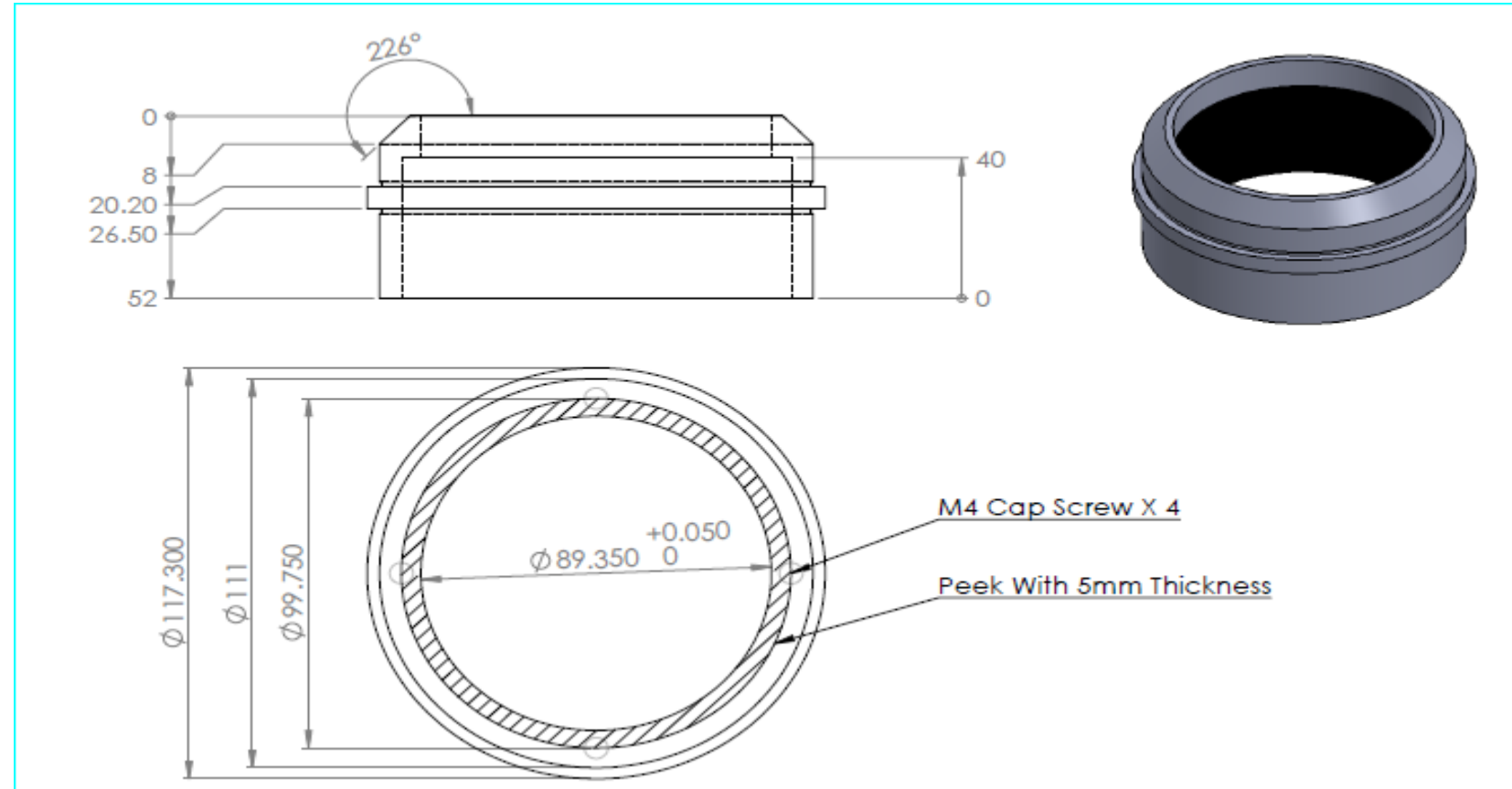
# Extensive repairs

- Casing split machining.
- Centre line boring after build up of worn out areas.
- Repair cracked portions in the casing.



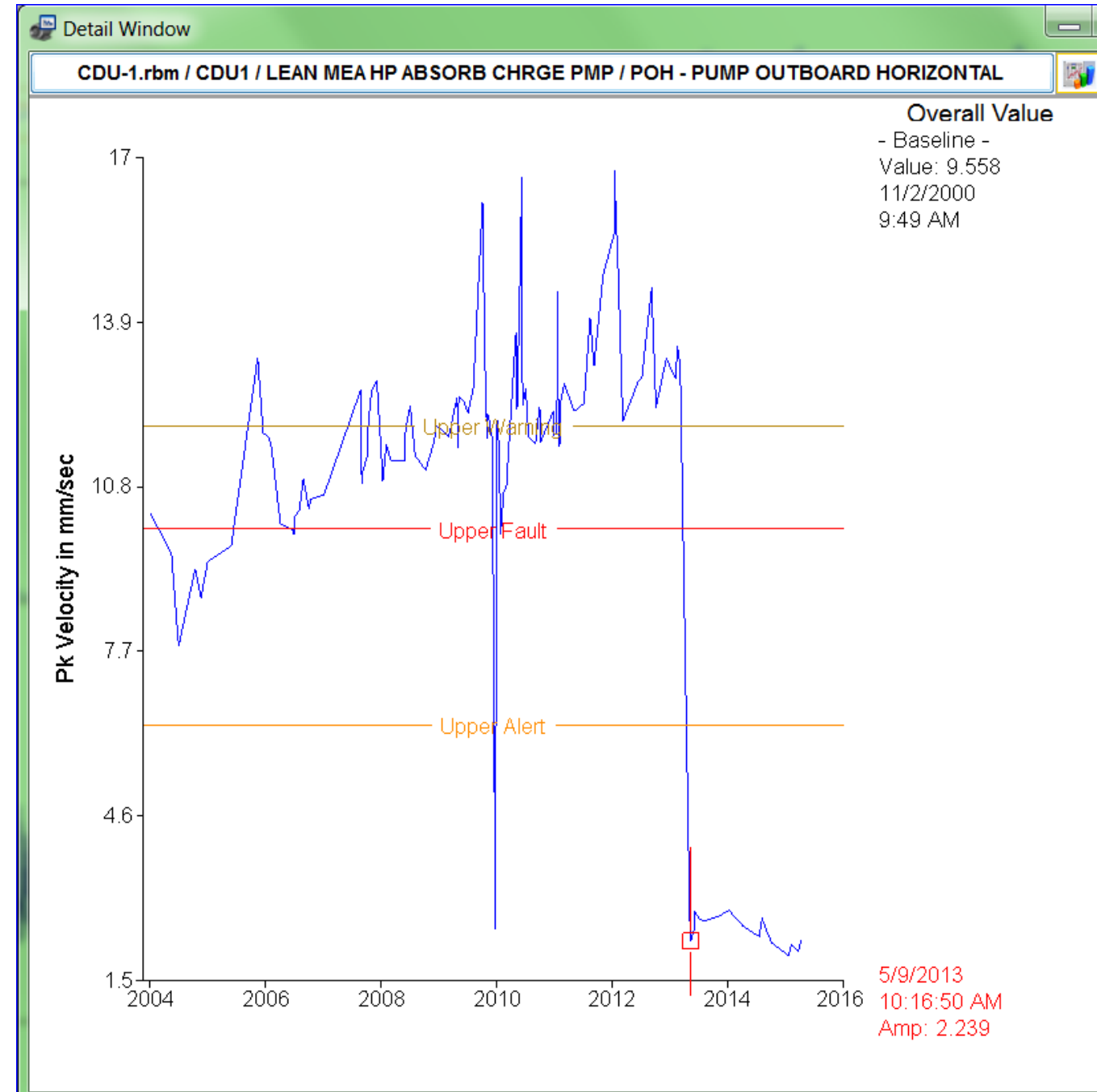
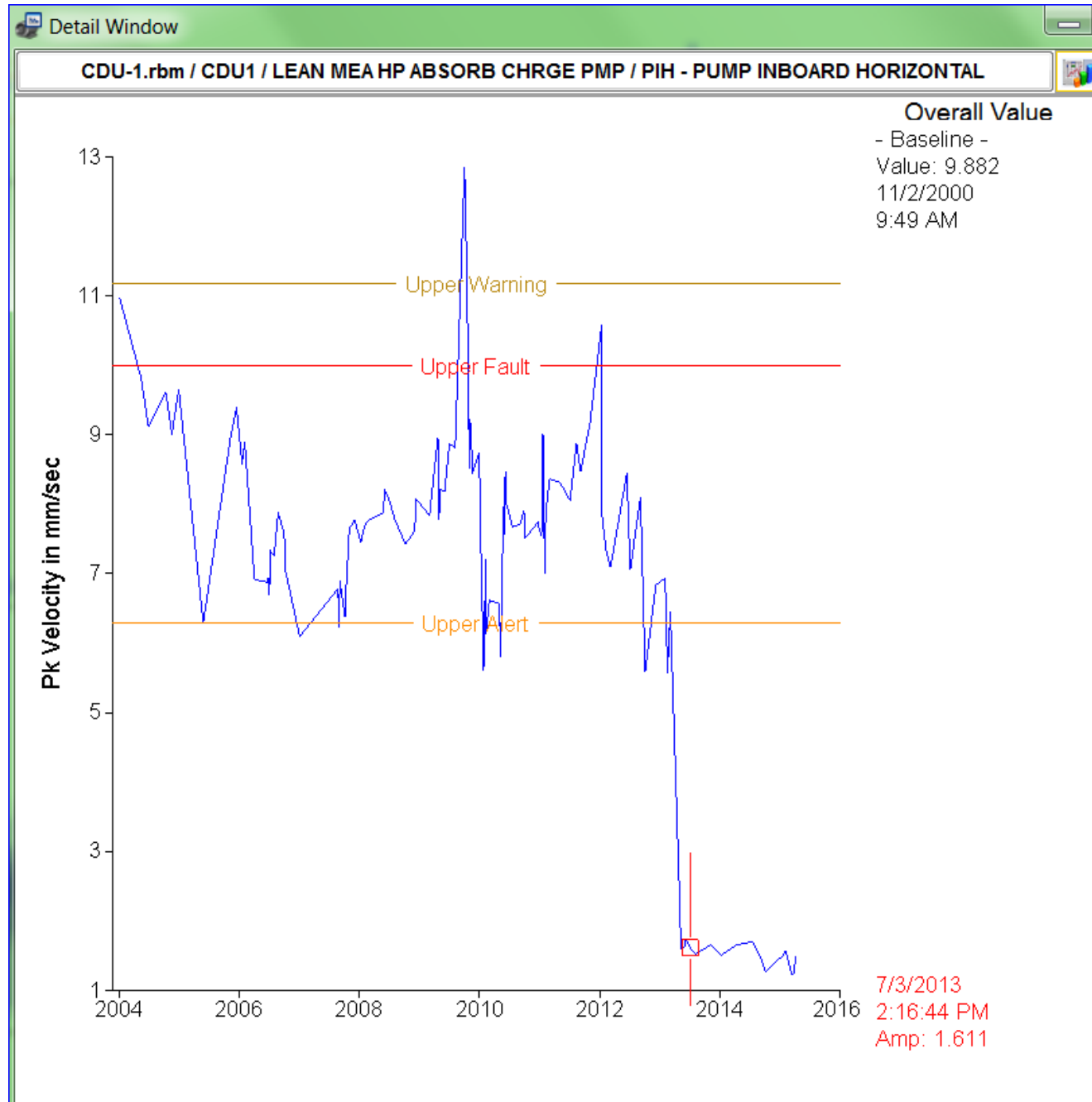
# Material Changes

- Changed Wear rings to Peek.
- In case of split casing it is quite a challenge to decide which to be made non metallic , rotor or stator specially for multistage pumps.
- It was decided to have all stationary parts with non metallic inserts to keep the ease of maintenance in mind.





# Machine Performance after upgrades



Significant reduction in pump bearing housing vibrations post overhaul  
No major failures in the pumps post 2013 for both the pumps.

# Summary of lessons learnt

- Bad Actors could be resolved without a major capex spend in most cases.
- Machine upgrades and implementation of latest technologies can help to eliminate the major issues.
- Carrying out Root Cause Analysis and ensuring the recommendations are implemented timely are the key.
- Support from OEM's and good repair facilities was key in our success.